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(54) Title of the invention Method and apparatus for cutting solid material by laser irradiation

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SPECIFICATION

1. TITLE OF THE INVENTION

Method and apparatus for cutting solid material by laser irradiation

2. WHAT IS CLAIMED IS :

(1) Method of cutting solid material by laser irradiation in which, at the time of cutting of solid material by laser irradiation, in order to effect repeated melt-cutting of the same cutting location, displacement of the position of the focal point of the laser beam in the direction of melt-cutting depth is effected in accordance with the welding depth of each time (Tr. note: 'welding' as in text), and, while cutting is effected, slag which is produced as the result of melting of the solid material after the melt-cutting of each time is cleaned away by a rotary cutter or by shot blasting, etc.

(2) Laser cutting apparatus which comprises a laser irradiation unit which is so constituted that the position of the focal point of a laser beam can be displaced in the direction of solid material melt-cutting depth, and a rotary cutter or shot blasting unit for the purpose of cleaning away the slag of melt-cut solid material.

3. DETAILED DESCRIPTION OF THE INVENTION

Field of industrial use

The present invention relates to a method of cutting solid material by laser irradiation and apparatus therefor which are made such that results equivalent to those in the case of cutting by a high-output laser are achieved by effecting repeated melt-cutting of the same location by a low-output laser.

Prior art

So far there have been hardly any practical examples of laser beam cutting and dismantling of solid materials, particularly reinforced concrete, steel-frame reinforced concrete, fibre reinforced concrete, fibre concrete, concrete and mortar and structures, etc. in which these are used, and, at present, such work is at the laboratory stage. Also, in cutting methods that are currently practised, the procedure in cutting is that the laser output, which is a factor in the improvement of the cutting performance, the cutting speed, points coinciding with the focal distances or focal points of condenser lenses or converging mirrors, the laser beam mode (intensity distribution) and the pressure and type of the assist gas are taken as parameters, and these parameters are changed and combined in various ways. In these cutting methods, cutting of target material is effected by keeping a laser cutting unit, together with its focusing unit, constant in the direction of cutting depth and moving it in one direction. By way of an apparatus for cutting by such procedure, there is the apparatus which was described in the disclosure of Japanese Laid-Open Patent Application No. 59-194805, and which is shown in Fig. 5. To give a summary description of this, in the drawing, a laser beam 1 is emitted from a laser oscillator not shown, goes via a torch section 2, and is radiated onto concrete material 3 constituting a target object. P is the irradiation point, which is approximately the focal point of the laser beam 1, and melt-cutting is effected going from this point towards the interior of the concrete material 3. Further, MgO, etc. constituting supplementary material is supplied to the melted material via a nozzle 4 by a supplementary material supply unit 5, and, after this has become mixed with the melted concrete and cools, it becomes brittle slag 6. Since this slag gathers in a groove 7 which is produced by melt-cutting, it is removed by rotating a wire brush 8. A fragmentation agent 9 for the purpose of breaking up the concrete material 3 is charged into the groove 7 from which the slag has been removed.

A laser cutting apparatus is constituted by installing parts such as the above in line on a machine frame 10, and this apparatus effects cutting of concrete material while moving in the direction of the arrow A.

Problems intended to be resolved by the invention

However, in a conventional method such as the above, since the procedure is that concrete material is cut by moving the cutting apparatus in one direction without changing the laser focal point location in the direction of cutting depth, the only way of achieving any great improvement in the working efficiency of cutting by this method and apparatus is to make the speed of displacement of the apparatus slow or to make the laser output large. If the speed of displacement of the apparatus is made slow, cutting takes a long time, and if the laser output is made large, the laser oscillator and power supply unit, etc. have to be made larger, with the consequence that transport of a set of equipment to a work site for the purpose of operations at a place other than a fixed location such as a factory, etc. is difficult, and also that the equipment becomes expensive.

Further, if the laser output is made large, it is not possible to achieve a stable output, and within currently marketed units, the output with CO_2 lasers is up to 10 kW, and with other lasers and the output with other lasers is 3 kW or less.

The present invention is one which has been devised in view of these prior art problems, and it has as its object to resolve these problems by establishing a method whereby repeated melt-cutting of the same location is effected while changing the position of the focal point of a laser in the direction of cutting depth.

Means for resolving the problems

The present invention is a method of cutting solid material by laser irradiation in which, at the time of cutting of solid material by laser irradiation, in order to effect repeated melt-cutting of the same cutting location, displacement of the position of the focal point of the laser beam in the direction of melt-cutting depth is effected in accordance with the melt-cutting depth of each time, and, while cutting is effected, slag which is produced as the result of melting of the solid material after the melt-cutting of each time is cleaned away by a rotary cutter or by shot blasting, etc. and, by way of an invention of an apparatus which is used in the practice of this method, it is a laser cutting apparatus which comprises a laser

irradiation unit which is so constituted that the position of the focal point of a laser beam can be displaced in the direction of solid material melt-cutting depth, and a rotary cutter or shot blasting unit for the purpose of cleaning away the slag of melt-cut solid material.

Effect

First, when the cutting apparatus is moved along a cutting location while the position of the focal point of a laser beam is set on the surface of solid material constituting an object which is to be cut, a melt-cut groove whose depth is inversely proportional to the speed of displacement of the cutting apparatus is formed in the solid material, and, if the solid material is, eg, concrete material, cooled and solidified slag adheres in this groove after the melt-cutting. The groove is accordingly cleaned by removing this slag by means of a rotary cutter or by means of shot blasting, etc. When, next, the laser beam's focal point position is moved to the bottom portion of the cleaned groove, and, while irradiation is effected, the laser cutting apparatus is moved again along the cutting location in the same way as before, this bottom portion of the groove is cut more deeply, and a deeper groove is formed. Hereupon, the slag which has formed again is removed by means such as noted above. Next, the laser focal point position is set in the bottom portion of this groove which has become deeper, and similar melt-cutting is repeatedly effected, with the result that the depth of the melt-cut groove reaches the rear surface of the solid material, and so the solid material becomes cut through. This repetition of melt-cutting by a low-output laser makes it possible to achieve results equivalent to those in the case of cutting with a high-output laser. The apparatus used at this time, is low-output laser cutting apparatus possessing a means which can move the position of the focal point of a laser beam.

Examples of implementation

Below, the invention will be described with reference to the drawings. Figs. 1-4 show examples of implementation of the invention.

First, to describe the structure, in Fig. 1, 1 indicates a laser cutting apparatus, and 2 is a machining head which constitutes the laser irradiation unit of this apparatus. A reflecting mirror 3 and a converging mirror 4, etc. are provided in this machining head 2, the arrangement being that a laser beam 5 emitted from a laser oscillator not shown is reflected and converged and is radiated onto solid material constituted by concrete material 6.

7 is a protective tube for the machining head 2, and is provided in order to prevent a fall of the laser power by shielding the laser beam from dust and smoke which are produced at the time of cutting of the concrete 6, and, in addition, penetration of such fumes into the path of the laser beam is prevented by blowing air into the protective tube 7 via an air blow-in port 8. 9 is an assist gas nozzle which is provided for the purpose of hastening melting of iron bars in the concrete by blowing an assist gas such as O_2, etc. onto the laser beam focal point position and also for the purpose of blowing away slag (dross) which is in a molten state. When this dross cools, it becomes glassy solid slag 10 which fills up a groove 11 formed by melt-cutting and adheres strongly to the groove's wall surface. The arrangement is therefore made such that this slag 10 is cut and pulverised by a rotary cutter 12 and is sucked up and discharged to the exterior by a cleaning unit 13.

14 is a computer control unit which moves the machining head 2 in the direction of melt-cutting depth in accordance with the groove 11 depth h detected by a sensor not shown and automatically controls the laser beam's focal point position. 15 is a control rod which is connected to a remote control unit not shown.

In order to produce a great melt-cutting depth, the focal distance of the laser beam 5 which is converged by the converging mirror 4 is set at about 1 m. What's the significance of 1m?

Next, the operation will be described.

First, the machining head 2 is adjusted in a manner such that the focal point position of the laser beam 5 comes on the surface of the concrete material 6. Next, when the laser cutting apparatus 1 is moved at a set speed along the concrete material cutting location, a melt-cut groove 11 with a depth h_1 which is related to the

subsequently discussed displacement speed is formed in the concrete material 6. While dross which is produced at this time is being blown away from the vicinity of the focal point position by the assist gas which is blown out from the assist gas nozzle 9, it cools in the groove 11, becomes glassy slag and adheres strongly to the wall of the groove 11. The adhering slag 10 is cut and pulverised by the rotary cutter 12, which moves integrally with the apparatus 1, and it is sucked into the cleaning unit 13 and discharged to the exterior. When the cutting location of the concrete material 6 has thus been melt-cut to a degree such that the groove 11 with a depth h_1 is formed, the apparatus 1 returns to the cutting start point of the cutting location, and, at the same time, the depth h_1 of the groove 11 is detected by the sensor not shown, and the resulting detection signal is sent to the computer control unit 14, whereupon the machining head 2 is controlled by the unit 14 and is moved in the direction of depth in order to bring the focal point position of the laser beam 5 into the bottom portion of the groove 11. Next, the laser cutting apparatus 1 is moved again at a set speed along the cutting location of the concrete material 6 in the same way as the time before, and, accompanying this movement, the concrete material 6 is melt-cut further, a groove 11 with a depth of $h_1 + h_2$ is formed, and slag which is in this groove is cut and pulverised by the rotary cutter 12, which has been caused to project further from the apparatus 1 by the distance h_2. and is discharged by the cleaning unit 13.

As the result of repetition of this melt-cutting operation by the laser cutting apparatus 1, the depth of the groove 11 increases, and the concrete material 6 is cut through.

Fig. 2 shows a 2nd example of implementation (in which parts which are the same as in the example of implementation described above have the same reference symbols attached thereto and a duplicated description thereof is omitted). In this example of implementation, a blast nozzle 17 is provided instead of the rotary cutter 12 of the example of implementation described above, dross is blown away by sand or grit which is jetted from this nozzle, the powder and grains consisting of a mixture of this sand or grit and dross are recovered into a cleaning unit 13 via a suction pipe 18, and compressed air causes the recovered powder and grains to go via a supply pipe 19 and be jetted again from the blast nozzle 17. 20 is a

plate which is for sealing purposes, and which, at the same time as the suction intake of powder and grains, partitions the groove 11 and defines a sealed space 21. Aspects such as the action of the machining head 2 and the method whereby repeated melt-cutting of the same cutting location is effected are the same as in the 1st example of implementation.

Fig. 3 shows a 3rd example of implementation. This is an example in which the suction pipe 18 for recovering sand or grit in the 2nd example of implementation is omitted, and blast material such as sand, etc. goes from a blast material tank 22 and through the supply pipe 19, is jetted from the blast nozzle 17, and is not re-used. Therefore, the structure is simpler than in the 2nd example of implementation. This apparatus can be used when powder and dust that are blown about do not cause problems in the working environment.

Fig. 4 is a graph showing the relations between the laser outputs and the melt-cut depths (the abovenoted groove 11 depths h_1, h_2, ...) produced by melt-cutting when repeated melt-cutting was effected in the above examples of implementation, and it shows that the cut depth (1-time cutting value 45 mm? 2-times cutting value 85 mm) when melt-cutting by a 5 kW output laser was effected 2 times, was greater than the cut depth (82 mm) when melt-cutting by a 10 kW output laser was effected 1 time (the apparatus displacement speed being 10 cm/min in both cases). In other words, there is no need for a laser with a high output such as an output exceeding 10 kW, and if repeated melt cutting by a laser with a low output of 5 kW to <10 kW is effected, it is possible to achieve the same results as in the case of cutting by a high-output laser. It is noted that the graph also shows that the cut depth (85 mm) when a laser with an output of 5 kW was used and melt-cutting was effected 2 times at a cutting speed of 10 cm/min was greater than the cut depth (82 mm) when melt-cutting was effected 1 time at a cutting speed of 5 cm/min.

Cut depth 45 mm. 40 mm.

Advantage of the invention

As described above, according to the invention, cutting of solid material such as concrete material, etc. can be effected easily and results better than those in the case of cutting by a high-output laser can be achieved by repeated melt-cutting by a low-output laser. Therefore for large equipment (laser oscillator, power supply unit,

etc.) and ancillary equipment for producing a large output are unnecessary, and this is very advantageous in terms of safety measures and cost.

4. BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic of a 1st example of implementation according to the invention, Fig. 2 is a schematic of a 2nd example of implementation, Fig. 3 is a schematic of a 3rd example of implementation. Fig. 4 is a graph showing relations between laser outputs and cut depths, and Fig. 5 is a schematic of a conventional example.

2 ... laser irradiation unit (machining head), 5 ... laser beam, 6 ... solid material (concrete material), 10 ... slag, 12 ... rotary cutter, 17 ... blast nozzle, 18 ... suction pipe, 19 ... supply pipe, 13, 17, 18, 19 ... shot blast unit.

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Key to Fig. 4 (text sheet 5)

1 Cut depth (mm)

2 Laser output (kW)

3 Concrete

4

	Laser output	5 kW	Cutting speed	10 cm/min	1-time cutting value
Δ	"	5 kW	"	10 cm/min	2-times cutting value

5 1-time cutting value

6 2-times cutting value

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㊿発明の名称　レーザー照射による固形材の切断方法及びその装置

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明　細　書

1. 発明の名称

レーザー照射による固形材の切断方法及びその装置

2. 特許請求の範囲

(1) レーザーを照射して固形材を切断するに際し、同一切断位置を繰返し溶断するために、毎回の溶接深さに応じてレーザービームの焦点位置を溶断深さ方向に移動するとともに、毎回の溶断後に固形材が溶融して生じる溶滓を回転カッタ又はショットブラスト等により除去清掃しつつ切断することを特徴とするレーザ照射による固形材の切断方法。

(2) レーザービームの焦点位置を固形材の溶断深さ方向に移動可能に構成したレーザー照射装置と、溶断した固形材の溶滓を除去清掃するための回転カッタ又はショットブラスト装置とを備えたことを特徴とするレーザー切断装置。

3. 発明の詳細な説明

〔産業上の利用分野〕

この発明は、低出力のレーザーによって同一切断位置を繰返し溶断することにより、大出力レーザーで切断した場合と同等の結果が得られるようにしたレーザー照射による固形材の切断方法及びその装置に関する。

〔従来の技術〕

固形材のうち、特に鉄筋コンクリート、鉄骨鉄筋コンクリート、ファイバー鉄筋コンクリート、ファイバーコンクリート、コンクリート、モルタルおよびそれらを用いた構造物等をレーザービームによって切断し解体する実際例は未だほとんど見られず、現在においては実験室的段階にある。

また、現在行われている切断方法は、切断性能を向上させる要因であるレーザー出力、切断速度、集光レンズ又は集光ミラーの焦点距離、焦点を合わせる位置、レーザービームモード（強度分布）、アシストガスの圧力とその種類等をパラメータとし、これらのパラメータをそれぞれ変化させて組合わせ、切断を行っている。但し、これらの切断方法は、レーザー切断装置を、その焦点位置を切

は密閉用プレートであって、粉粒体を吸引する際に、溝11を仕切って密閉空間21を構成する。また、加工ヘッド2の動作及び同一切断位置を繰返し溶断する方法等については前記第1の実施例と同様である。

第3図に第3の実施例を示す。これは第2実施例においてサンドやグリッドを回収するための吸引管18を欠除したものであって、ブラスト材タンク22から供給管19を介してブラストノズル17から噴射し、サンド等のブラスト材は再使用しない。従って、構成は第2実施例よりさらに簡単になっているが、この装置は吹飛ばされた粉塵が作業環境において問題を生じない場合に使用されるものである。

第4図は以上の実施例において、同一切断位置を繰返し溶断を行った場合のレーザー出力と溶断された切断深さ(前述の溝11の深さh_1, h_2, ……)との関係を示す線図であって、出力5KWのレーザーで2回溶断した場合の切断深さ(1回切り値45㎜, 2回切り値85㎜)は、出力10KWのレーザーで1回溶断した場合の切断深さ(82㎜)よりも大きいことを示している。(但し、いずれも装置の移動速度は10㎝/min)。すなわち、10KWを超えるような大出力のレーザーで切断を行う必要がなく、5KW乃至10KW未満の低出力レーザーで繰返し溶断を行えば、大出力レーザーで切断した場合と同じ結果が得られることになる。なお、図は出力5KWのレーザーを用い、切断速度を10㎝/minで2回溶断した場合の切断深さ(85㎜)は、切断速度5㎝/minで1回溶断した場合の切断深さ(82㎜)よりも大きいことも示している。

〔発明の効果〕

以上説明したように、この発明によれば、低出力レーザーの繰返し溶断で、コンクリート材等の固形物の切断が容易に行われ、大出力レーザーで切断した場合以上の結果が得られる。従って、大出力のための大型の装置(レーザー発振器, 電源装置等)及び付帯設備を必要とせず、安全対策上及びコスト上、きわめて有利であるという効果が得られる。

4.図面の簡単な説明

第1図は本発明に係る第1の実施例の概要図、第2図は第2の実施例の概要図、第3図は第3の実施例の概要図、第4図はレーザー出力と切断深さとの関係を示す線図、第5図は従来例の概要図である。

2……レーザー照射装置(加工ヘッド)、5……レーザービーム、6……固形材(コンクリート材)、10……溶滓、12……回転カッタ、13……清掃装置、17……ブラストノズル、18……吸引管、19……供給管、13, 17, 18, 19……ショットブラスト装置。

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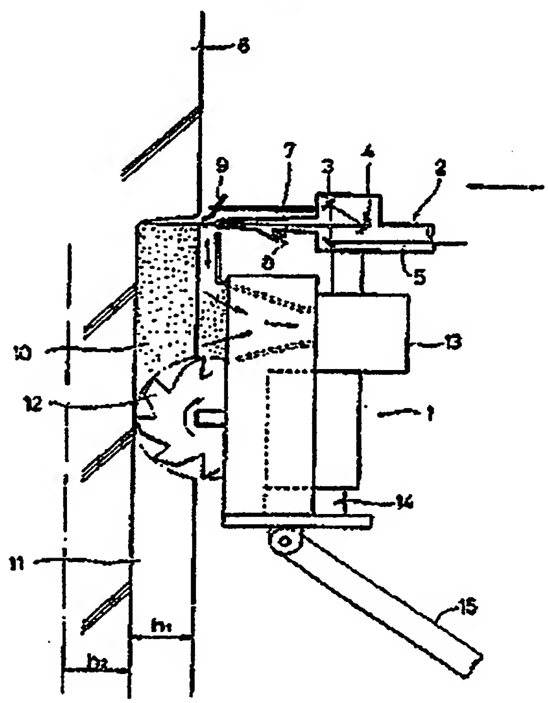
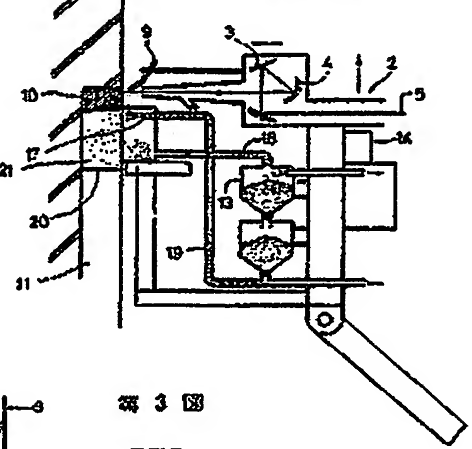
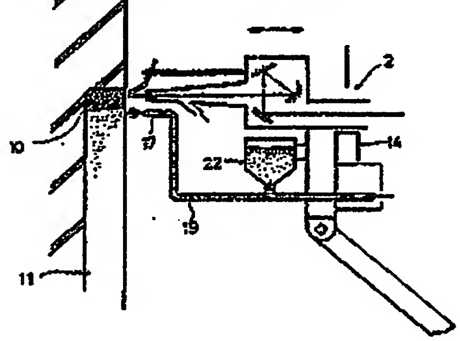
第1図



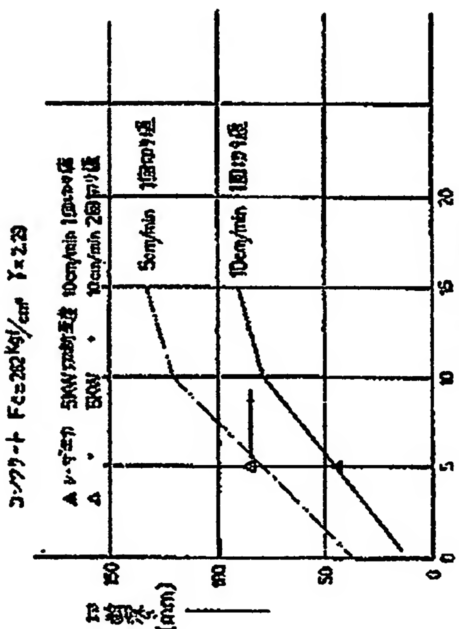
第2図



第3図



第4図



第5図